

GENESIS AND HISTORY OF THE CMST PROGRAM

DOE ENVIRONMENTAL GOAL (Set November 1, 1989)

Former U. S. Department of Energy (DOE) Secretary of Energy James D. Watkins established the Office of Environmental Restoration and Waste Management (ERWM) and Office of Technology Development (OTD) on November 1, 1989, and adopted a goal to clean up 80 percent of DOE nuclear sites by 2006 and the more challenging DOE sites by 2030. Achieving this goal in a cost-effective manner required the development and implementation of safer and more efficient technologies for *site characterization and remediation, facility deactivation and decommissioning, and waste treatment and disposal*. These paired cleanup objectives are essential to cleaning up and restoring DOE sites throughout the United States for subsequent use and development. As part of its Integrated Program to accomplish these objectives, the ERWM created the Characterization, Monitoring, and Sensor Technology (CMST) program to be the focal point and integrator of environmental characterization and contaminant measurement technology development efforts.

NEED FOR ENVIRONMENTAL RESTORATION TECHNOLOGY DEVELOPMENT

To achieve its environmental cleanup objectives, ERWM first needed to characterize the waste inventory that had been accumulating for over 40 years at DOE sites, including thousands of contaminated facilities, contaminated equipment, soil contaminated by spills, waste disposal sites, and contaminant migration in the subsurface. Many of the environmental remediation technologies available in FY 1990 were inadequate or not economically feasible to implement at DOE sites. Some existing technologies were not capable of accurately assessing or characterizing the environmental status, defining specific cleanup requirements, or quantifying remediation success. In many cases, the technologies or strategies needed to deal with the diverse assortment of contaminated sites, with their unique combinations and levels of contaminants that include both radioactive and toxic materials, did not even exist. In addition, DOE needed a team approach that transcended organizational boundaries to evaluate and coordinate the development of technologies and methodologies to efficiently and cost-effectively achieve the following objectives.

Site Characterization and Remediation

The first set of cleanup objectives is to characterize contaminated sites in sufficient detail to make possible efficient, reliable, and defensible remediation. To achieve these objectives in a timely manner, DOE needed faster, less costly, and less environmentally intrusive methods for characterizing subsurface contamination and its potential for moving within the subsurface environment. DOE also needed technologies to monitor remedial processes in real time as well as to measure the effectiveness of remediation. In cases where complete remediation and restoration are not viable options, DOE needed technologies to contain or immobilize (stabilize) contaminants and to monitor the long-term effectiveness of those solutions.

Conventional remediation technologies were not designed to safely retrieve and treat extremely corrosive and/or highly radioactive wastes stored in surface and underground tanks or in waste lagoons, or to recover buried wastes (some of which are explosive, spontaneously ignite, and/or contain high levels of radioactivity, heavy metals, and hazardous organic solvents). In other instances, where large volumes of soil contain unacceptable levels of radionuclides, heavy metals, or hazardous organic compounds, conventional technologies that rely on excavation, treatment, and re-disposal clearly are neither cost-effective nor environmentally acceptable and expose workers to health and safety hazards. Significant technological advances in remediating groundwater are also necessary, especially for situations involving dense non-aqueous phase liquids and for nitrates in deep aquifers.

Facility Deactivation and Decommissioning

The second set of cleanup objectives is to close down, dismantle, decontaminate, and dispose of facilities and their contents at DOE sites to make decommissioning possible. Technology development was needed to ensure that the deactivation and decommissioning processes used at DOE sites were cost-effective and that they met all health, safety, and environmental regulations. Since many available decontamination processes were expensive, created excessive waste, and required modifications to satisfy existing regulations, innovative technologies and approaches were needed to meet requirements and to conserve resources.

The DOE facilities that need to be decontaminated, dismantled, and disposed of range from underground storage tanks and hot cells to mammoth uranium enrichment and plutonium processing plants. Each facility has radioactive contaminants and, in some instances, toxic substances contained in or on equipment that is difficult to remove because of its unique and complex design. DOE facilities slated for deactivation and decommissioning also include uranium enrichment and fabrication facilities, nuclear production reactors, and fuel reprocessing plants that have massive contaminated structures. Innovative technologies are needed to safely survey and distinguish the various contaminants on the surface and within equipment, pipes, and other facility materials, to reduce worker exposure and minimize waste.

Waste Treatment and Disposal

The third set of cleanup objectives is to treat, minimize, and dispose of contaminated materials and to recycle clean materials. In the process of remediating a site, contaminated soil and substances, including groundwater, are separated from clean soil and groundwater; the clean soil and groundwater are recycled. The extracted waste and contaminated solids are typically packaged in steel drums and deposited in a landfill. Non-destructive assay technologies are needed to confirm that the contents of the drums conform to landfill disposal requirements/regulations prior to delivery and burial.

Specially designed technologies are needed for characterizing, removing, and treating the contents of underground storage tanks and wastewater lagoons. Waste tanks and lagoons often contain significant quantities of highly radioactive wastes mixed with heavy metals, corrosive chemicals, and/or hazardous organic compounds that make personnel entry unacceptable. Remotely operated instrumentation and analysis systems are needed to reduce radiological exposure to workers and to monitor waste extraction conduits, such as pipelines, and treatment processes, such as vitrification and stabilization.

Continuous emissions monitors (CEMs) are needed at incinerators to replace existing emission sampling technologies that rely on periodically sampling and analyzing stack emissions with data becoming available only after a substantial time lapse. CEMs must be capable of continuously analyzing what is in the emissions and measuring the amounts of those substances. In particular, CEMs must be capable of measuring, in "real time" and under adverse conditions, emissions containing low levels of the metals specified in the Resource Conservation and Recovery Act (RCRA), hazardous chemical compounds, and radioactive elements from, for example, the incineration of mixed wastes. CEMs must also provide facility operators with the real-time data needed to prevent violation of regulatory standards.

NEED FOR AN INTEGRATED TECHNOLOGY DEVELOPMENT PROGRAM

Technology development is proceeding at a rapid pace at various commercial, academic, and federal laboratory organizations. The diversity of those development activities make it desirable to have a team devoted to overseeing and coordinating DOE-sponsored technology development to avoid duplication of effort to provide expertise, bring in technologies and strategies from other government agencies, and to help refine and then satisfy the environmental technology needs of DOE sites. Indeed, a characterization, monitoring, and sensor technology program driven by DOE needs is essential for sensible and cost-effective resource allocation and management. Furthermore, in addition to efficient resource utilization, there is great potential to improve worker safety and to lessen environmental impacts.

ERWM made its CMST program the focal point for developing the environmental characterization and measurement technology needed for site cleanup. In its role as an integrator of technology development, CMST employed the participation of Characterization Technical Support Groups and Integrated Program Technology Support Groups. In an effort to further focus resources and address technology development opportunities, ERWM implemented Integrated Programs and Integrated Demonstrations

An Integrated Program focuses on technologies to solve a specific aspect of a waste management or environmental problem; the technology solution can be either unique to a site or common to many sites. An Integrated Program supports applied research to develop innovative technologies in key application areas organized around specific activities required in each stage of the remediation process (e.g., characterization, treatment, and disposal).

An Integrated Demonstration is the cost-effective mechanism that assembles a group of related and synergistic technologies to evaluate their performance individually or as a complete system in correcting waste management and environmental problems from cradle to grave.

The CMST program was an active participant in the Integrated Programs and Integrated Demonstrations.

THE EARLY YEARS OF THE CMST INTEGRATED PROGRAM (FY 1990 TO 1994)

Initial Characterization, Monitoring, and Sensor Technology (CMST) activities began in FY 1990. The early focus of the CMST was to identify the environmental restoration and waste management technology needs of the DOE sites, and to conduct a research and development program to satisfy those needs. From its inception through March 1992, it was managed directly by OTD at DOE Headquarters (HQ) with the assistance of BDM International, Ames Laboratory, and Los Alamos National Laboratory.

During the OTD Mid-Year Review in March 1992, Ames Laboratory was designated the primary field organization for CMST supporting the HQ Program Manager. OTD also adopted the Strategic Plan developed by Ames Laboratory in collaboration with other CMST program participants. Ames Laboratory, as the primary field support organization, was responsible for bringing together and utilizing the expertise needed for evaluating technology development proposals and the merits and progress of ongoing projects, and for collecting information and documenting CMST research and development projects in support of numerous ERWM activities throughout the DOE Complex.

SCOPE AND MANAGEMENT OF THE CMST INTEGRATED PROGRAM

The scope of CMST encompassed the broad spectrum of chemical and physical measurement and analysis technologies for the characterization and monitoring of contaminant materials, waste streams, and environmental contamination at DOE sites. The environmental media to be characterized and quantitated included air, soil, groundwater, waste forms, and waste containers. The activity range extended from identification and analysis of needs to the delivery and post-application evaluation of technology performance. The initial CMST program development and application areas were:

- Technologies that characterize, monitor, and sense mobile contaminants and define mobile contaminant pathways.
- Tools and strategies to provide better and more cost-effective site and waste and waste form characterization.
- Characterization of buried waste, the contents of underground storage tanks, and facilities to be decontaminated and decommissioned.
- Remediation process and waste treatment process monitoring.
- Characterization of high-level, transuranic, and mixed waste, and contaminated soil, material, and equipment for final disposition.

CMST Management Policies and Strategies

Since the success of OTD programs depended on the cooperation of many organizations working in concert, the following strategic management policies were adopted by OTD in March 1992.

- Work with the DOE ERWM Office of Waste Management (EM-30) and Office of Environmental Restoration (EM-40) by participating in the following technology exchange activities: Technology Integration, Technology Diffusion, Technology Transfer, and Technology Adaptation and Adoption. Obtain and validate information about their needs and schedule requirements.
- Work with the Integrated Demonstration and Integrated Program Technical Support Groups (Chemical Waste Landfill/Mixed Waste Landfill, Underground Storage Tanks, Buried Waste, Uranium in Soil, Plutonium in Soil, Volatile Organic Compounds in Non-Arid Soil and Groundwater, and Volatile Organic Compounds in Arid Soil and Groundwater) to share expertise and gain intimate knowledge of DOE EM technology needs and deficiencies. Capture planning and schedule requirements for Integrated Demonstrations and Integrated Programs so that the CMST program can accurately anticipate technology needs.
- Work in a manner that demonstrates open-mindedness and lack of bias. The CMST program must encourage the involvement of all DOE sites and laboratories, other federal agencies, and commercial and academic sectors, avoiding the tendency to support the DOE laboratories when more attractive alternatives exist.
- Prepare and distribute a newsletter that describes pertinent ERWM needs, identifies contact persons who are responsible for supplying information about available technologies that address those needs, and provides "snapshots" of newly available or emerging technologies from all sources.

CMST Technology Development Priorities

The initial technology development priorities were categorized as follows:

Characterizing Contaminants and Contaminant Pathways

- Airborne Contaminants (stack monitors for organic compounds, radionuclides, heavy metals)
- Transport Properties of Media (continuity of clay layers, non-intrusive methods for monitoring subsurface contaminant migration, improved methods for obtaining hydrologic permeability, improved high-resolution surface-fielded geophysical methods to define shallow systems)
- Waterborne Contaminants (real-time monitoring of process effluents for targeted organic compounds, heavy metals, radionuclides; *in situ* monitoring of volatile organic compounds)
- Soil Contaminants (uranium, plutonium, or other heavy metals in soil, organic contaminants)
- Real-Time Monitoring (volatile organic compounds, radionuclides, heavy metals, particulates)

Site Characterization Strategies

- Improved Sampling Strategies (use of *a priori* information, dynamic sampling strategies, quantification of the influence of uncertainty)
- Development and Application of Appropriate Data Quality Objectives

Waste Characterization Strategies

- Location of Buried Waste Containers and Objects (location of buried drums, resolution between buried metallic objects)
- Underground Storage Tanks (integrity and contents of underground storage tanks)
- Contents of drums (transuranic waste versus mixed wastes).
- Characterizing the Integrity of Waste Containers (field test methods for integrity of 55-gallon drums and Waste Isolation Pilot Plant waste packages)

CMST Technology Development Initiatives

The CMST program technology development initiatives included:

- Field Deployable, Rapid-Turnaround Chemical Characterization Instrumentation (advanced technology mass spectrometric, electrochemical, and spot test instrumentation for volatile organic compounds, inorganic pollutants, and radioisotopes in soil, groundwater, and storage tanks)
- Complex-Wide Protocol for the Establishment of Data Quality Objectives (characterization data and data quality required to support regulatory and other decisions regarding environmental restoration and waste management)
- Field Deployable, Data Driven, Adaptive Characterization Guidance Package (improved, timely guidance for field personnel on where to sample next for maximum return on pollutant distribution based upon spatial statistical analysis of all previously obtained characterization results)
- Large Area Imaging Sensor System for Surface Contamination Mapping (needed for mapping radioactively contaminated surfaces in facilities and surface soil contamination)
- Advanced Technology Continuous Emissions Monitors (needed to monitor and characterize metals and particulates)
- Advanced Technology Chemical Sensor and Sensor Placement Systems for Post-Closure Monitoring (volatile organic compounds, chromate ions, mercuric ion, and elemental mercury)
- System for Visualization and Analysis of Combined Data Streams from Geographical Location and Multiple Characterization Technologies (to improve the usefulness and total value of data from separate characterization techniques, including the whole array of surface and remote geophysical and other sensing technologies as well as the whole array of field and laboratory chemical analysis techniques)
- Advanced Near-Surface and Borehole Seismic and Other Non-Intrusive Geophysical Technologies for Location and Characterization of Buried Waste (present methods are inadequate)
- Non-Destructive Assay/Non-Destructive Evaluation Technologies (needed for determining the contents of waste drums)
- Integration and Application of Chemical and Radioactivity Sensors in Robotic Characterization, Retrieval, Decontamination, and Waste Processing Systems (needed for characterization of underground storage tanks, spent fuel retrieval and reprocessing, and deactivation and decommissioning not presently being addressed)
- Airborne Remote Sensing

A NEW APPROACH TO TECHNOLOGY DEVELOPMENT (FY 1994 to 1999)

Although technology research and development efforts were quite successful, it became apparent that a better approach was needed to overcome some obstacles and to speed up DOE site cleanup.

Consequently, in August 1993, the Assistant Secretary of Environmental Management established a Working Group to develop and implement a new management approach to environmental research and development within the entire ERWM.

During FY 1994, the Working Group established a framework and strategy for coordinating efforts among DOE organizations, Management and Operations (M&O) contractors, the national laboratories, other government agencies, the scientific community, industry, academia, and the affected public. Full implementation of the new approach occurred in FY 1995. Concurrently, in FY 1995, the CMST-Integrated Program (CMST-IP) was transformed into the Characterization, Monitoring, and Sensor Technology Crosscutting Program (CMST-CP).

In FY 1995 the ERWM was transformed into the Office of Environmental Management (EM) and the OTD was transformed into the Office of Science and Technology (OST). The newly formed organizations aimed to build upon existing programs and to seek continual improvement of all DOE EM operations and processes. To assist in this endeavor, Site Technology Coordination Groups (STCG) were established at each major DOE site to identify their technology development needs.

The objectives of the new EM/OST management approach included better prioritizing research projects and fostering an enhanced level of technology development by involving academia and private industry. Another objective was to overcome obstacles to DOE site cleanup by focusing efforts on the specific needs of customers, users, regulators, and stakeholders and by keeping them informed of progress. Key features of the approach were:

- Establishing five Focus Areas and three Crosscutting Programs to address the most pressing environmental cleanup problems at DOE sites.
- Focusing technology development activities on major environmental management problems.
- Coordinating management of scientific and development activities in support of environmental management in the five Focus Areas.
- Teaming with internal DOE customers to identify, develop, and implement needed technologies.
- Focusing resources in national laboratories more effectively.
- Involving industry in developing and implementing solutions (including technology transfer *into* DOE and *from* DOE to the private sector).
- Coordinating basic research by involving academia and other research organizations to stimulate technological breakthroughs.
- Enhancing the involvement of regulators and stakeholders in implementing new technologies.

Benefits of the New Approach

A keystone for implementation of the new approach was to encourage the development of technologies that were better, faster, safer, and more cost-effective than those currently available. More importantly, the new approach was adopted to foster implementation of new and innovative environmental technologies, thereby facilitating the national commitment to achieving long-term environmental, energy, and economic goals. An important benefit of the new approach was the creation of investment returns for developing new technologies—technology dividends. These technology dividends result from partnerships and leveraging *within* government and *between* government and the private sector. The partnerships could consist of technology developers, technology users, problem holders, and problem solvers. EM technology dividends included:

- Cleanup of sites posing the greatest threats to human health, safety, and the environment.
- Materials reused and recycled, instead of thrown away or freshly contaminated.
- Pollution prevented.
- More effective and efficient industrial processes, leading to greater U.S. global competitiveness.
- Technology transfer to other countries.
- Employment opportunities with new businesses and existing businesses.

Establishment of Focus Areas in FY 1995

Five Focus Areas were established to target major remediation and waste management problem areas within the DOE Complex. These problem areas were targeted on the basis of risk, prevalence, or need for technology development to meet environmental requirements and regulations. The following are the Focus Areas established in FY 1995 with their original descriptions:

Contaminant Plume Containment and Remediation Focus Area

Unconfined hazardous and radioactive contaminants in soil and groundwater exist throughout the DOE Complex. There is insufficient information at most sites on the distribution and concentration of contaminants. The migration of some contaminants threatens water resources and, in some cases, has already had an adverse impact on the off-site environment. Many current characterization, containment, and treatment technologies are ineffective or costly. Improvements are needed in characterization and data interpretation methods, containment systems, and *in situ* treatment.

Mixed Waste Characterization, Treatment, and Disposal Focus Area

DOE faces major technical challenges in the management of low-level radioactive mixed waste. Conflicting regulations together with a lack of definitive mixed waste treatment standards hamper mixed waste treatment and disposal. Disposal capacity for mixed waste is expensive and severely limited. DOE now spends millions of dollars annually to store mixed waste because of the lack of accepted treatment technologies and disposal capacity. In addition, currently available waste management practices require extensive and costly waste characterization before disposal. Therefore, DOE must pursue technology that leads to better and less expensive characterization, retrieval, handling, treatment, and disposal of mixed waste.

Radioactive Tank Waste Remediation Focus Area

Across the DOE Complex, hundreds of large storage tanks contain hundreds of thousands of cubic meters of high-level mixed waste. The primary areas of concern are deteriorating tank structures and consequent leakage of their contents. Research and technology development activities must focus on the development of safe, reliable, and cost-effective methods for characterizing, retrieving, treating, and permanently disposing of the wastes.

Landfill Stabilization Focus Area

Numerous DOE landfills pose significant remediation challenges. Some existing landfills have contaminants that are migrating, and require interim containment prior to final remediation. Materials buried in retrievable storage pose another problem. Retrieval systems must be developed to reduce worker exposure and secondary waste quantities. Another high-priority need is to develop *in situ* methods for containment and treatment.

Decontamination and Decommissioning Focus Area

The aging of DOE weapons facilities, along with the reduction in nuclear weapons production, has resulted in a need to transition, decommission, deactivate, and dispose of numerous facilities contaminated with radionuclides and hazardous materials. While building and scrap materials at the sites are a potential resource with a significant economic value, current regulations lack clear release standards. This indirectly discourages the recovery, recycling, and/or reuse of these resources. The development of enhanced technologies for the decontamination of these materials, and effective communication of the low relative risks involved, will facilitate the recovery, recycling, and/or reuse of these resources. Improved material removal, handling, and processing technologies will enhance worker safety and reduce cost.

The Focus Areas were redefined in FY 1997. Two Focus Areas related to soil and groundwater, Contaminant Plume and Remediation Focus Area and Land Stabilization Focus Area, were combined into the Subsurface Contaminants Focus Area and a new Plutonium Focus Area was added. In FY 1999 the Plutonium Focus Area was enlarged in scope and renamed the Nuclear Materials Focus Area. In FY 2000 the Mixed Waste Focus Area was enlarged to include transuranic wastes and was renamed the Transuranics/Mixed Waste Focus Area (TMFA).

Establishment of Crosscutting Programs in FY 1995

Three Crosscutting Programs were established in FY 1995 to manage the development of technologies that overlap individual Focus Areas:

Characterization, Monitoring, and Sensor Technology Crosscutting Program

DOE is required to characterize more than 3,700 contaminated sites, 1.5 million barrels of stored waste, 385,000 cubic meters of high-level waste in tanks, and from 1,700 to 7,000 facilities before remediation, treatment, and facility transitioning commence. During remediation, treatment, and site closure,

monitoring technologies are needed to ensure worker safety and effective cleanup. Cost-effective technologies are needed for all DOE environmental characterization requirements.

Efficient Separations and Processing Crosscutting Program

Separation and treatment technologies are needed to treat and immobilize a broad range of radioactive wastes. In some cases, separation technologies do not exist; in others, improvements are needed to reduce costs, reduce secondary waste volumes, and improve waste form quality. Separation technologies are also needed for the environmental restoration of DOE sites, for groundwater and soil cleanup, and for the decontamination and decommissioning of facilities. Many separation agents developed for waste treatment can be adapted for environmental restoration needs.

Robotics Technology Crosscutting Program

DOE waste disposal efforts have particular issues--access, safety, final disposal, and cost efficiency. Due to hazardous radiation, massive waste loads, and restricted entryways, many sites are inaccessible for human labor. It is unsafe to expose humans to radiation, harmful chemicals, and injurious mechanical objects. Human labor requires higher compensation, the need for expensive protective clothing, and stringent decontamination procedures. Robotic systems are safe, efficient, and cost-effective means to automate the handling and processing of mixed waste and characterizing and/or retrieving storage tank waste. Systems can also be designed for surveillance, characterization, cleanup, and decommissioning of retired DOE facilities.

MANAGEMENT OF THE CMST CROSSCUTTING PROGRAM (FY 1990 to Present)

While the fundamental technological objectives of the CMST program have remained essentially the same since its inception, the management approach has changed several times. As stated earlier, during the initial phase from FY 1990 through March 1992, CMST program activities were managed entirely by DOE HQ with the support of BDM International, Ames Laboratory, and Los Alamos National Laboratory. From mid-March 1992 until FY 1996, Ames Laboratory was the primary Field organization coordinating CMST Program activities for HQ. During FY 1996 OST designated the DOE Nevada Operations Office (NV) the CMST Field Coordinator organization, and NV became the CMST Field Lead organization in FY 1998. In FY 2000, the management role of the OST Crosscutting Programs, including CMST-CP, was changed to a Focus Area Centered approach. The following contrasts the primary changes as they affected the CMST-CP.

From its inception through FY 1999, CMST-CP was funded directly by the DOE OST (EM-50), and was responsible for delivering CMST solutions to the DOE sites in support of the DOE Office of Waste Management (EM-30) and the DOE Office of Environmental Restoration (EM-40). Beginning In FY 2000, the CMST-CP is being funded by the OST Focus Areas and is responsible for working with them to identify technology gaps and CMST solutions to the DOE sites in support of the DOE EM Offices of Integration and Disposition (EM-20), Site Closure (EM-30), and Project Completion (EM-40), and the OST Office of Long Term Stewardship (EM-51).

CMST PROGRAM MANAGERS AND COORDINATORS

The following time periods are approximate. The period(s) an individual served is given by fiscal year. This may not fully represent the entire time period an individual served.

Stanley Wolf, DOE/OTD

CMST HQ Program Manager, FY 1990-1992

David Roelant, BDM International/ Professional Analysis, Inc. - Bechtel Nevada

CMST HQ Contractor Lead, FY 1991-FY1997

CMST Field Program Coordinator, FY 1997-1999

William Haas, Ames Laboratory

CMST Field Program Coordinator, FY 1992-1993

Caroline Purdy, DOE/OTD/OST

CMST HQ Program Manager, FY 1992-1997

Paul Wang, Ames Laboratory

CMST Field Program Coordinator, FY 1994

CMST Field Program Technical Coordinator, FY 1995

CMST Field Technical Coordinator, FY 1996-1998

John Jones, DOE/NV

CMST Project Manager (on assignment to HQ), FY 1996

CMST Field Program Manager, FY 1996-1997

CMST Field Technical Manager, FY 2000

Charles Nalezny, DOE/OST

CMST HQ Program Manager, FY 1998-1999

David Hippensteel, DOE/NV

CMST Field Program Manager, FY 1997-1998

Dirk Schmidhoffer, DOE/NV

CMST Field Program Manager, FY 1998-1999

Joseph Ginanni, DOE/NV

CMST Field Program Manager, FY 1999-2000

Edward Rizkalla, DOE/OST

CMST HQ Point of Contact, FY 2000

Charles Davis, Professional Analysis, Inc. - Bechtel Nevada

CMST Field Program Coordinator FY 1999-2000

Beth Moore, DOE/OST

CMST HQ Point of Contact, FY 2000

CURRENT PROGRAM STATUS AND FUTURE OUTLOOK

CMST-sponsored research and development has resulted in the evaluation, development, and application of many characterization, monitoring, and sensor technology solutions to environmental restoration and waste management problems at DOE sites. The CMST program develops technologies to satisfy specific needs identified in Need Statements made by the DOE Site Technology Coordination Groups, striving to develop technologies that are safer, faster, less costly, more efficacious, and less physically invasive than previously used approaches. The CMST program also develops innovative technologies to solve Site Environmental Restoration and Waste Management problems where no suitable technologies previously existed.

CMST projects have made major technological advances in methods used for site, facility, and waste characterization. They have made a major impact in the areas of real-time *in situ* monitoring for site characterization, waste stream and thermal treatment process control, and surveying contaminated facilities and equipment.

At present approximately 120 CMST program technologies have been evaluated and/or developed, demonstrated, and applied to DOE EM problems at DOE sites. Approximately 40 technologies developed by the CMST program are commercially available. Nevertheless there remain dozens of environmental problems that need new solutions.

Accurate characterization of the nature and extent of soil, groundwater, and facility contamination can have a dramatic effect on the amount of material that is ultimately subjected to remediation, stabilization, and/or disposal. The treatment options depend to a large extent on accurately determining the distribution and concentrations of various contaminants. Similarly, real-time control and optimization of waste treatment systems can be accomplished only if reliable, real-time monitors are available, thus enabling continuous monitoring and adjustments for changing waste conditions. Finally, DOE EM will need to validate system performance upon completion of site remediation and waste disposal as part of its environmental restoration and site stewardship responsibilities. Sensitive and reliable sensors and monitoring programs will be critical to protecting public health and assuring the necessary high confidence in engineered solutions.

In the recent report entitled "Research Needs in Subsurface Science," prepared by the National Research Council (2000) certain of the sensor and monitoring technology needs are specifically identified:

"Development of methods for designing monitoring systems to detect current conditions and changes in system behaviors. These methods may involve the application of conceptual, mathematical, and statistical models to determine the types and locations of observation systems and prediction of the spatial and temporal resolutions at which observations need to be made."

"Research to support the development of methods to monitor fluid and gaseous fluxes through the unsaturated zone, including both direct (e.g., in situ sensors) and indirect (e.g., using plants and animals) over long time periods. Included is research addressing physical instrumentation as well as measurement techniques, the latter including measurement strategies and data analysis (including statistical) approaches."

Research and development continues to be needed to design both *in situ* and remote sensors that can discriminate more effectively, have greater sensitivity, and enable real-time or near real-time continuous assessments of changing conditions spanning many channels of input (corresponding to many contaminants under observation). Corresponding applied and developmental research is needed to transform the findings of basic research and innovative concepts into functioning, reliable instruments and methodologies for confronting the challenges and demands of *in situ* applications both in the field or within active or closed facilities.

The ability to accurately characterize and monitor the existence and migration of contaminants is paramount to cost-effective environmental restoration and waste management strategies. An improved ability to detect and assess the spatial distribution of different types of contaminants will enable more precise, tailored approaches to different conditions at each DOE site. Similarly, in the treatment of wastes, such as those from Deactivation and Decommissioning, the ability to accurately scan wastes in real time or near real time and to perform appropriate separation and segregation could result in significant life cycle cost savings. And, in pursuit of final disposal and site stewardship options, improved sensors will increase confidence and provide a more sensitive, early warning when system failures occur. The CMST team has the experience and technical capability to deliver innovative technologies to satisfy DOE site characterization, monitoring, and sensor technology needs.

Selected highlights and a list of the technologies evaluated and/or developed by the CMST program during the past decade are presented in Appendix A.